



HAL
open science

Efficient sensitivity analysis of the EMC BCI test

Etse Kokouvi, Lionel Pichon, Mohamed Touré, Mariem Ksouri

► **To cite this version:**

Etse Kokouvi, Lionel Pichon, Mohamed Touré, Mariem Ksouri. Efficient sensitivity analysis of the EMC BCI test. 20th International Symposium on Electromagnetic Fields in Mechatronics, Electrical and Electronic Engineering, 2021, Lodz, Poland. hal-03779642

HAL Id: hal-03779642

<https://hal.science/hal-03779642v1>

Submitted on 17 Sep 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Efficient sensitivity analysis of the EMC BCI test

Etse Kokouvi, Lionel Pichon

GeePs | Group of electrical engineering - Paris, CNRS,
CentraleSupélec, Université Paris-Saclay, Sorbonne Université,
3 & 11 rue Joliot-Curie, 91192 Gif-sur-Yvette, France
etse.kokouvi@geeeps.centralesupelec.fr

Mohamed Touré, Mariem Ksouri

EFI Automotive
77 Allée des Grandes Combes Beynost, 01700 Miribel

Abstract—The BCI (Bulk Current Injection) test in electromagnetic compatibility is a reference scenario widely used in industry for the conducted immunity evaluation of electronic equipment. Quantifying the influence of all geometrical parameters is a key challenge. This work shows that a fast sensitivity analysis can be performed with the use of a small number of sampling data thanks to metamodelling used to compute Sobol indices. The interest of the approach is demonstrated through a susceptibility analysis involving a realistic multi-conductors line under probe.

Keywords— EMC, BCI (Bulk Current Injection) test, sensitivity analysis, metamodelling.

I. INTRODUCTION

The electrification of transportation means involving massive use of on-board electronics and increasingly compact integration requires ensuring good cohabitation of various electronic components. Considering EMC (Electromagnetic compatibility) from the design stage and compliance with electromagnetic standards has therefore become essential for automotive and aeronautical equipment manufacturers [1]. Cables are often the longest part of electrical systems and are one of the preferred propagation paths for electromagnetic disturbances. The BCI (Bulk Current Injection) test, ranked among the most severe because of the injected disturbance levels, has become one of the most widely used tests in industry for the conducted immunity test. BCI test is a non-intrusive technique that aims to confirm that RF signals, when coupled to interconnect cables and/or power lines, will not cause performance degradation against the specifications of the equipment under test (EUT). The BCI test has gradually become a benchmark in terms of international standards in several areas such as military (MIL-STD 461), aeronautics (RTCA / DO-160), commercial (IEC 61000-4-6) and automotive (ISO 11452-4). Recent studies have also shown the possibility of using the injection probe to measure the susceptibility to electromagnetic radiation of equipment [2,3]. Given the interest of this test, several authors have contributed to the characterization and modelling of the injection probe and the calibration device as well as the study of probe to cable coupling [4-6]. The injection probe forms with the conductors a RF transformer where the current injection probe (IP) can be considered as the primary and the cables clamped the secondary. In [7], a single conductor is mounted under the injection probe in order to characterize and interpret the equivalent electrical circuit of the injection probe. However, results of this study cannot be extended to the practical case of multiwire under probe as the investigation is carried on a single wire under probe condition. In [8], an equivalent electrical model of the injection probe with a wire harness at the secondary is

presented. In this study, the influence of several geometrical factors on the BCI test was investigated. However, it does not provide the comparative sensitivity of the BCI test to the various parameters considered. Diop et al [9] conducted a sensitivity study of the BCI test with the 2D Flux software. As the study is based on a 2D representation of the device, it does not reflect the practice of the test. For example, the length of the conductors and the transmission phenomena are not taken into account. Additionally, the 2D primary winding does not exactly reflect the actual configuration. Therefore, the sensitivity analysis conducted in this study, although showing the influence of a number of parameters, does not correspond to the practical case of the BCI test.

The novelty of this work is to show that a fast sensitivity analysis based on metamodelling allows to quantify and prioritize the various parameters that influence the repeatability of the BCI test. The studied configuration is that of the FCC-F130A which is recommended up to 400 MHz. The geometry and the material parameters are described in [7, 8]. A meta-model based on a polynomial chaos expansion combined with a 3D modeling tool (CST) allows to calculate the Sobol indices [10, 11] which quantify the relative influence of each parameter.

II. ELECTROMAGNETIC MODEL OF BCI SET-UP

A. Injection Probe

The injection probe is presented in Figure 1. The metallic frame of the probe is a perfect electric conductor (PEC) with a thin slit separating the two portions of the inner frame.

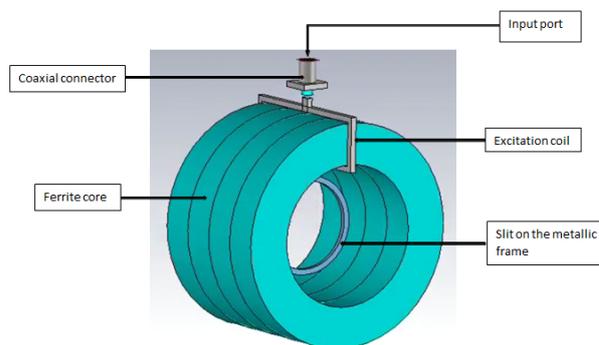


Fig. 1. 3D model of the injection probe

B. Calibration set-up

The probe is located at the midpoint of the calibration fixture as shown on Figure 2. In practice, this step is also used to find the power that will be injected during the test. The computation of the S-parameters between the three ports of the structure is important to determine the probe coupling factor. When they are determined, the input power required to produce the desired current can be evaluated.

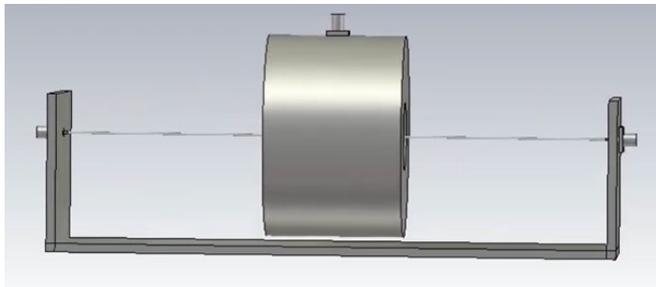


Fig. 2. 3D model of the injection probe mounted on a calibration jig

III. SENSITIVITY ANALYSIS

The configuration test described in section II is modeled with the 3D electromagnetic solver CST and is shown in Figure 3. This configuration includes 19 coated long wires clamped under the IP and each terminated by a 50 Ohms resistance. The wires are at 51 mm above the ground plane. In order to study uncertainties related to the BCI test, 4 parameters have been considered: The wire length (L), the section of conductors (r-cd), distance between the injection probe and the equipment under test (P), the height of the harness above the ground plane (Plan). A meta-model based on a sparse polynomial chaos expansion (PCE) is built using 3 sample data for each parameter.

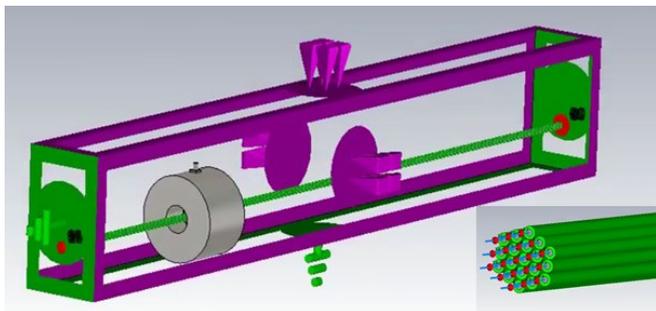


Fig. 3. 3D model of the injection probe

The interest of PCE is to give analytical expressions of Sobol's indices highlighting the most impacting parameters. As an illustration, Figure 4 shows the Sobol indices reflecting the impact of the considered parameters on the induced current at 200 MHz. For the considered parameters, the wire length is the one most influencing the induced current at the wire ends. The position of the input port of the IP is the second one. The other two parameters do not influence significantly the current at the end of conductors. Work is in progress to deduce such conclusion over the wide frequency band.

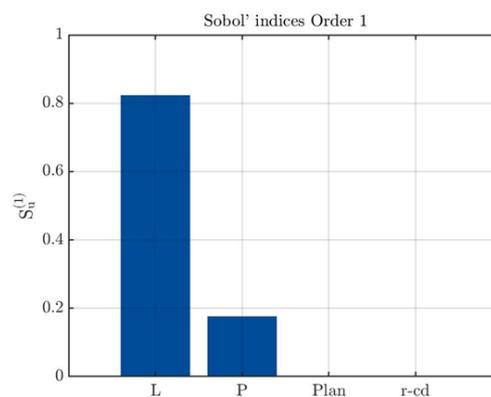


Fig. 4. Relative influence of each geometrical parameter on the induced current

REFERENCES

- [1] Road Vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy-part 4: harness excitation methods, ISO 11452-4, Dec. 2011.
- [2] L. Badini, G. Spadacini, F. Grassi, S. A. Pignari and P. Pelissou, "A Rationale for Statistical Correlation of Conducted and Radiated Susceptibility Testing in Aerospace EMC," in IEEE Transactions on Electromagnetic Compatibility, vol. 59, no. 5, pp. 1576-1585, Oct. 2017, doi: 10.1109/TEMC.2017.2678762.
- [3] J. W. Adams, J. Cruz and D. Melquist, "Comparison measurements of currents induced by radiation and injection," in IEEE Transactions on Electromagnetic Compatibility, vol. 34, no. 3, pp. 360-362, Aug. 1992, doi: 10.1109/15.155856.
- [4] F. Grassi, F. Marliani and S. A. Pignari, "Circuit Modeling of Injection Probes for Bulk Current Injection," in IEEE Transactions on Electromagnetic Compatibility, vol. 49, no. 3, pp. 563-576, Aug. 2007, doi: 10.1109/TEMC.2007.902385.
- [5] S. Miropolsky, S. Frei, and J. Frensch, "Modeling of bulk current injection (BCI) setups for virtual automotive IC tests," in Proc. Int. Symp. Electromagn. Compat. Europe, Wroclaw, Poland, Sep. 13-17, 2010, pp. 1-6.
- [6] P. DeRoy and S. Piper, "Full-wave modeling of bulk current injection probe coupling to multi-conductor cable bundles," 2016 IEEE International Symposium on Electromagnetic Compatibility (EMC), Ottawa, ON, 2016, pp. 770-774, doi: 10.1109/IEMC.2016.7571746.
- [7] F. Grassi, F. Marliani and S. A. Pignari, "Circuit Modeling of Injection Probes for Bulk Current Injection," in IEEE Transactions on Electromagnetic Compatibility, vol. 49, no. 3, pp. 563-576, Aug. 2007, doi: 10.1109/TEMC.2007.902385.
- [8] N. Toscani, F. Grassi, G. Spadacini and S. A. Pignari, "Circuit and Electromagnetic Modeling of Bulk Current Injection Test Setups Involving Complex Wiring Harnesses," in IEEE Transactions on Electromagnetic Compatibility, vol. 60, no. 6, pp. 1752-1760, Dec. 2018.
- [9] M. S. Diop et al., "2D FEM model for BCI probe-to-cables coupling with several conductors at the secondary winding," 2017 International Symposium on Electromagnetic Compatibility - EMC EUROPE, Angers, 2017, pp. 1-5, doi: 10.1109/EMCEurope.2017.8094799.
- [10] S. Marelli, B. Sudret, UQLabuser manual -Polynomial chaos expansions, Report # UQLab-V1.3-104, Chair of Risk, Safety and Uncertainty Quantification, ETH Zurich, Switzerland, 2019.
- [11] Yao Pei, Lionel Pichon, Mohamed Bensetti, Yann Le-Bihan. Uncertainty quantification in the design of wireless power transfer systems. Open Physics, De Gruyter, 2020, 18 (1), pp.391-396.